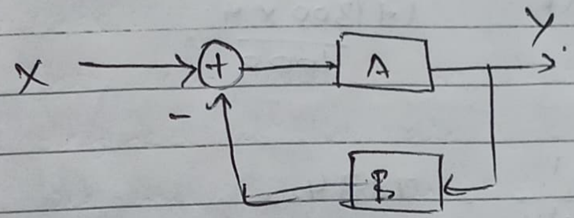
Assignment 5.

1. Given circuit:



$A = 1000\ V/V.$

$$\frac{A}{1+AK} = 100\ V/V.$$

i) Find the tolerance in closed loop gain if ope loop tolerance is 30%.

∴ for +30%.

$A = 1300.$

$$\frac{A}{1+AK} = \frac{1300}{1+1300 \times K} \quad —(1)$$

⇒ K = ? A

$$\frac{A}{1+AK} = 100.$$

$$\Rightarrow \frac{1000}{1+AK} = 100$$

$\Rightarrow 1+AK = 10.$

$AK = 9.$

$$\boxed{K = 9/1000}$$

$\Rightarrow$ from (1)

$$\frac{A'}{1+A'K} = \frac{1300}{1+\frac{1300 \times 9}{1000}}$$

$$\Rightarrow \frac{A'}{1+A'K} = 78.74.$$

for -30%.

$$\frac{700}{1+\frac{9}{1000} \times 700} = 95.89\%$$

$\therefore$ tolerance of closed loop $= \boxed{21.26\%}$.

ii) if $\frac{A}{1+AK} = 10.$

$$\Rightarrow \frac{1000}{1+1000K} = 10.$$

$1+1000K = 100$

$1000K = 99$

$K = \frac{99}{1000}$.

$\Rightarrow$ ~~K = 0.~~ 1%.

$$\Rightarrow \frac{1300}{1+\frac{1300 \times 99}{1000}} \Rightarrow \frac{1300}{\cancel{13K}} \Rightarrow 10.02\%$$

for $A = 700$.

$$\frac{700}{1 + 700 \times \frac{99}{1000}} = 9.95$$

$\Rightarrow$ tolerance $= \cancel{0.0205}$ $\frac{10 - 9.95}{10}$

$\Rightarrow \boxed{0.005\%}$

iii) When 2 stages are cascaded

gain $= 10 \times 10 = 100$ V/V. —(1)

tolerance

$\Rightarrow 0.005 \times 0.005$

$= \cancel{0.0025}$. $\boxed{2.5 \times 10^{-5}}$ %. —(2)

2. Problem 7.2.

$$v_{n,in}^2 = 4KT \left(\frac{2}{3} \frac{1}{g_{m1}} + \frac{2}{3} \frac{g_{m2}}{g_{m1}^2} \right)$$

$$V_{n,in} = \sqrt{4KT \frac{2}{3}} \sqrt{\frac{1}{g_{m1}} + \frac{g_{m2}}{g_{m1}^2}}.$$

$$\frac{g_{m2}}{g_{m1}^2} = \left(\frac{1}{5}\right)^2 \frac{1}{g_{m2}} \Rightarrow g_{m2} = \left(\frac{1}{5}\right)^2 g_{m1}.$$

$$g_m = \frac{2I_D}{V_{gs}-V_T}$$

$$\Rightarrow V_{gs}-V_T = \frac{2I_D}{g_m}.$$

$\therefore$ Output swing $= V_{DD} - (V_{gs_1}-V_{T}) - [(V_{gs_2}-V_{T_2})]$.

$$= V_{DD} - 2I_D\left(\frac{1}{g_{m_1}} + \frac{1}{g_{m_2}}\right).$$

$$= V_{DD} - 2I_D\left(\frac{1}{g_{m_1}}\right)(1+r^2).$$

$$g_{m_1} = \sqrt{2I_D \mu_n C_{ox} W/L} \approx 1.986 \text{ mA/V}.$$

$\therefore$ output swing $= 3V - 2(.1mA)\left(\frac{1}{1.980}\right)(26)$

$\Rightarrow$ Output swing $= 0.38$ V.

Problem 7.6:

a) $$|A_v| = \frac{g_m R_D}{1+g_m R_S}.$$

$$\overline{V_{n\,out}^2} = 4KTR_D + 4KT\,\tfrac{2}{3}\,\tfrac{1}{g_m}\left(\frac{g_m R_D}{1+g_m R_S}\right)^2 + 4KT\,\frac{1}{R_S}\left(\frac{R_S}{1/g_m + R_S}\right)^2 R_D^2$$

$$= 4KTR_D + 4KT\frac{2}{3}\frac{1}{g_m}\left(\frac{g_m R_D}{1+g_m R_S}\right)^2 + 4KTR_S\left(\frac{g_m R_D}{1+g_m R_S}\right)^2.$$

$$v_{n,in}^2 = \frac{v_{n,out}^2}{|A_v|^2}.$$

b). $$|A_v| = g_m\left(1/g_m \,||\, R_s\right).$$

$$v_{n,out}^2 = \left(4KT\,\tfrac{2}{3}g_m + 4KT\frac{1}{R_s}\right)\left(1/g_m \,||\, R_s\right)^2.$$

$$v_{n,in}^2 = \frac{v_{n,out}^2}{|A_v|^2}.$$

$$= 4KT\,\frac{2}{3}\,\frac{1}{g_m} + 4KT\,\frac{1}{g_m^2 R_s}.$$

c) $$|A_v| = \frac{g_m}{1+\left(g_m + \frac{1}{R_F}\right)R_s}\cdot R_{out}.$$

$$R_{out} = R_s + (1+g_m R_s)R_F.$$

$$v_{n,out}^2 = \left(\frac{4KT\,2/3\,g_m}{\left(1+\left(g_m + 1/R_F\right)R_s\right)^2} + \frac{4KT\,1/R_F}{\left(1+\left(g_m+\frac{1}{R_F}\right)R_s\right)^2}\right.$$

$$\left. + \frac{4KT\,1/R_s\cdot R_s^2}{\left(R_s + 1/g_m \,||\, R_F\right)^2}\right) \times R_{out}^2.$$

$$v_{n,in}^2 = 4KT\left(\frac{2}{3}\frac{1}{g_m} + \frac{1}{g_m^2 R_F} + R_s\left(1+\frac{1}{g_m R_F}\right)^2\right)$$

d) $$|A_v| = \frac{g_{m1}}{1+g_{m1}R_s} \times R_{out}.$$

$$R_{out} = \frac{1}{g_{m_2}}$$

$$v_{n,out}^2 = 4kT\frac{2}{3}g_{m_2}R_{out}^2 + 4kT\frac{2}{3}\frac{1}{g_{m_1}}(A_v)^2 +$$

$$4kT\frac{1}{R_S}\left(\frac{R_S}{1/g_{m_1}+R_S}\right)^2 R_{out}^2$$

$$v_{n,in}^2 = 4kT\left[\frac{2}{3}\frac{1}{g_{m_1}} + R_S + \frac{2}{3}g_{m_2}\left(\frac{1+g_{m_1}R_S}{g_{m_1}}\right)^2\right]$$

e) $|A_v| = g_{m_1}R_D$

$$v_{n,out}^2 = \left(4kT\frac{2}{3}g_{m_1} + 4kT\frac{1}{R_D}\right)R_D^2$$

$$v_{n,in}^2 = 4kT\left(\frac{2}{3}\frac{1}{g_{m_1}} + \frac{1}{g_{m_1}^2 R_D}\right)$$

f) $|A_v| = g_{m_1}\left(\frac{g_{m_2}R_S}{1+g_{m_2}R_S}\right)R_D$

$$v_{n,out}^2 = \left[4kT\frac{1}{R_D} + 4kT\frac{2}{3}\frac{1}{g_{m_2}}\left(\frac{g_{m_2}}{1+g_{m_2}R_S}\right)^2 + 4kT\frac{2}{3}\frac{1}{g_{m_1}}\left(\frac{g_m R_S}{1+g_m R_S}\right) + kT\right]R_D^2$$

$$v_{n,in}^2 = 4kT\left[\frac{2}{3}g_{m_1} + \frac{2}{3}\frac{1}{g_{m_1}}\frac{1}{(g_{m_1}R_S)^2} + \frac{1}{g_m R_S} + \frac{1}{g_m^2 R_D}\left(\frac{1+g_{m_2}R_S}{g_{m_2}R_S}\right)^2\right]$$

3. Short note on non-linearity in diff. circuit.

It is the used to measure performance in DAC, ADC.

It refers to constant relation between the change in output & input.

$$DNL(i) = \frac{V_{out}(i+1) - V_{out}(i)}{\text{ideal LSB step width}} - 1.$$

4. Problem 9.4.

$\left(\frac{W}{L}\right)_{1..8} = \frac{100}{0.5}$, $I_{SS} = 1\,mA$, $V_{b1} = 1.7V$,

$r = 0.$

a) $V_{in,CM\,min} = V_{ISS} + V_{GS1}$.

$$V_{OD3} = V_{GS3} - V_{th} = \left[\frac{2 I_{D3}}{(\mu_n C_{ox} W/L)}\right]^{1/2}$$

$$= \left[\frac{2(0.5)}{350 \times 383.6 \times 10^{-9} \times \frac{100}{0.5}}\right]^{1/2}.$$

$$\boxed{= 0.159\,V}$$

$$\boxed{V_{in,CM,max} = 1.7 - 0.159 = 1.541\,V}$$

b) $V_x = ?$

$$V_{GS7} - V_{thp} = \left[\frac{2 I_{D7}}{\mu_p C_{ox} \left(\frac{W}{L_{eff}}\right)}\right]^{1/2}$$

$$= 0.289.$$

$V_{GS7} = 0.289 + V_{thp} = 1.089\ V.$

$V_x = V_{DD} - V_{GS7} = 3 - 1.089.$

$\boxed{V_x = 1.911\ V}$

c) $V_{GS3} = V_{GS4} = 0.159\ V + V_{thn}.$

$V_{GS4} = 0.7 + 0.159. = 0.859\ V.$

Max Swing = $0.7 - 0.859 + 0.7$

$\boxed{\text{Max Output Swing} = 0.541\ V}$

d) $V_{b2} < V_x + V_{thp} - |V_{GS5}|. = 1.086\ V.$

$V_{b2} < 1.622\ V.$

$\boxed{1.11\ V < V_{b2} < 1.62\ V}$

c) As M_3, M_4, M_5, M_6 have negligible noise

Input reffered noise :

$$4KT\gamma\left(\frac{1}{g_{m12}} + \frac{g_{m78}}{g_m^2 {}_{42}}\right)\times 2.$$

d) ~~$\sqrt{84}$~~

$= 5.45\times10^{-18}\ V^2/H_2.$

$$\boxed{\sqrt{N} = 2.34\times10^{-9}\ V/\sqrt{H_2}}$$